UNCLASSIFIED

AD 201641

Armed Services Technical Information Agency

ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA

FOR
MICRO-CARD
CONTROL ONLY

1 OF 1

AD 201641

Technical Report **R-012** ELECTROLYSIS OF SEA WATER, OF SEA WATER FORTIFIED WITH SALT, AND FRESH (TAP) WATER FORTIFIED WITH SALT

20 December 1958

U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

AD 201641

ELECTROLYSIS OF SEA WATER, OF SEA WATER FORTIFIED WITH SALT, AND FRESH (TAP) WATER FORTIFIED WITH SALT

NY 310 004-7
Final Report

Type C

20 December 1958

by

T. Roe, Jr.,
A. E. Hanna, and
H. Hochman

U. S. NAVAL CIVIL ENGINEERING
LABORATORY
Port Hueneme, California

THIS
PAGE
IS
MISSING
IN
ORIGINAL
DOCUMENT

SUMMARY

OBJECT OF PROJECT

To develop effective devices and apparatus for BW or CW decontamination.

OBJECT OF SUBPROJECT

To develop the equipment and process for the production of sodium hypochlorite by the electrolysis of sea water and thus eliminate logistic and storage problems associated with the production of hypochlorite from chlorine and alkali and with the deterioration of stored hypochlorite.

OBJECT OF THIS REPORT

To show, by means of experimental data, the extent to which sodium hypochlorite can be produced for decontamination purposes by the electrolysis of sea water, sea water fortified with salt, and fresh (tap) water fortified with salt.

RESULTS

Using multiple pass operation, parallel plate cells can produce a maximum of 2.03% (20,300 ppm) available chlorine, from sea water saturated with salt, if the initial solution temperature is maintained throughout the operation by the use of heat exchangers between the cells. Under the same conditions, a maximum of 1.55% (15,500 ppm) available chlorine can be produced from fresh (tap) water saturated with salt and a maximum of 0.82% (8,200 ppm) can be produced from sea water.

ABSTRACT

The U. S. Naval Civil Engineering Laboratory, Port Hueneme, California, was requested by the Chief of Civil Engineers, U. S. Navy, to investigate the practicability of producing sodium hypochlorite decontaminating solutions by the electrolysis of sea water, thus eliminating the logistic and storage problems associated with the production of hypochlorite from chlorine and alkali, and the deterioration of stored hypochlorite. The Laboratory work included development of equipment and processes for the production of sodium hypochlorite by the electrolysis of sea water. This paper presents experimental data which shows the extent to which sodium hypochlorite can be produced for decontamination purposes by the electrolysis of sea water, sea water fortified with salt, and fresh (tap) water fortified with salt. The results of twenty-five test runs are listed. Using multiple pass operation, two parallel plate cells can produce a maximum of 2.03% (20,300 ppm) available chlorine from sea water saturated with salt, if the initial solution temperature is maintained throughout the operation by the use of heat exchangers between cells. Under the same conditions, a maximum of 1.55% (15,500 ppm) available chlorine can be produced from fresh (tap) water saturated with salt and a maximum of 0.82% (8,200 ppm) can be produced from sea water.

CONTENTS

TABLES

ILLUSTRATIONS

viii

ix

INTRODUCTION

The U.S. Naval Civil Engineering Laboratory, Port Hueneme, California, was requested by the Chief of Civil Engineers, U.S. Navy, to investigate the practicability of producing sodium hypochlorite decontamination solutions by the electrolysis of sea water. The Laboratory performed the required investigation under Project NY 310 004-7, and, in addition, determined the extent of the increase of available chlorine concentration which could occur by the electrolysis of sea water containing added amounts of salt, and fresh (tap) water saturated with salt. Electrolytic production of hypochlorite solutions would eliminate logistic and storage problems associated with their production from liquid chlorine and lime and with the deterioration of stored calcium hypochlorite.

Two identical parallel plate cells were designed and fabricated by the Laboratory, and then were operated under varying conditions. The cells are a stacked parallel type, a design which makes for a simple, easily maintained, rugged unit. An electrode system using graphite anodes and titanium cathodes was found to have desirable electrical and anti-corrosive properties.

This report presents discussion of design and fabrication of two parallel plate electrolytic cells, three different electrode systems, auxiliary equipment, the maximum quantities of available chlorine produced under varying conditions and the procedure of the investigations.

HISTORICAL BACKGROUND

It is the mission of the Bureau of Yards and Docks to keep advanced bases functioning efficiently at all times. During wartime rapid decontamination of areas subjected to biological or chemical attack would be of major importance in restoring the usefulness of any advanced base.

Hypochlorites are among the most active decontaminating agents available today. They are available at advanced bases in the solid form (calcium hypochlorite) or they may be prepared by the reaction of liquid

chlorine with an alkali, such as lime. Thus, the effective decontamination of a base subjected to chemical or biological attack is directly dependent on the quantities cf calcium hypochlorite or of liquid chlorine and lime on hand at the time of attack. This presents a logistic and storage problem of considerable proportion. Calcium hypochlorite slowly deteriorates on standing, and the rate of deterioration is increased greatly in hot humid climates. Liquid chlorine and lime can be stored for long periods of time but require special equipment and care in handling and mixing.

Sodium hypochlorite can be produced by the electrolysis of salt solutions and thus, under subtask NY 310 004-7, the Laboratory investigated the feasibility of producing this material by the electrolysis of sea water. In the initial work[1] on this project, two experimental cells were designed, fabricated, and operated under varying conditions. It was found that up to 0.2 percent available chlorine could be produced from sea water in one pass through one cell, and that both recycling the effluent through the cell and the addition of salt to sea water increased the available chlorine concentration. It was also noted that passage through the cell raised the temperature of the influent. During recycling experiments, each successive pass produced an additional rise in temperature. At the same time, the rate of production of available chlorine decreased with each successive pass through the cell. This decreasing rate of chlorine production was attributed to both the increased electrolysis of hypochlorite as its concentration increased and to thermal decomposition at the higher temperatures.

EQUIPMENT

Electrolytic Cells

Two parallel plate electrolytic cells were designed and fabricated (Figures 1 through 3). The electrode system of each cell consists of a series of anodes and cathodes, stacked alternately, and separated from one another by neoprene gaskets; the top and bottom of the cell are plastic plates and the entire stack is held together by eight 1/4 in. steel rods. This design makes it possible to construct cells with any number of electrode plates; also, plate materials of any thickness can be used because the spacing between the plates is determined only by the thickness of the neoprene gaskets. The cells used in this phase of the project contain three cathodes and two anodes to give effective anode and cathode areas of 320 square inches.

[1] NCEL Technical Note N-300, "Electrolysis of Sea Water," T. Roe, Jr., and H. Hochman, 10 May 1957.
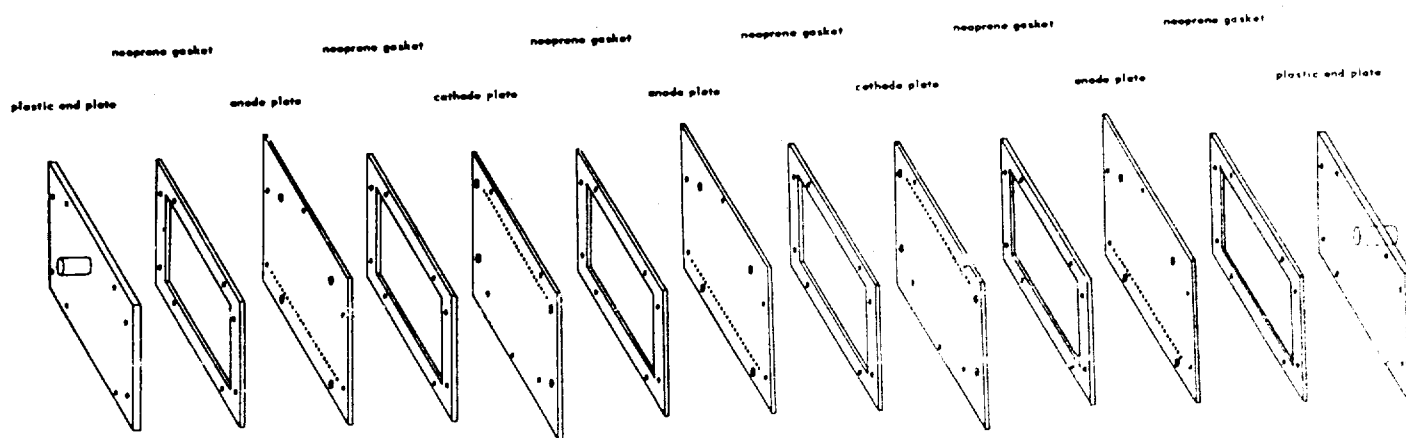
Figure 1. Exploded view of stacked parallel plate cell.
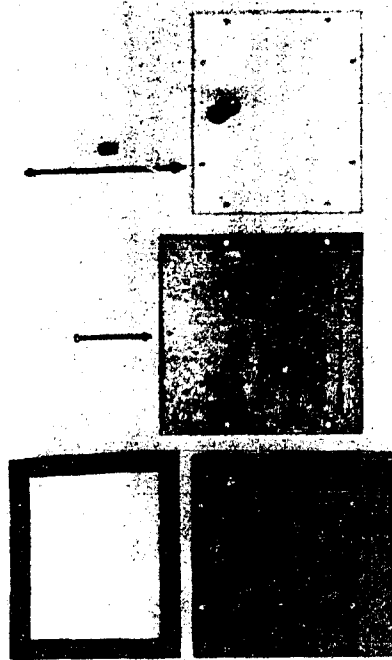
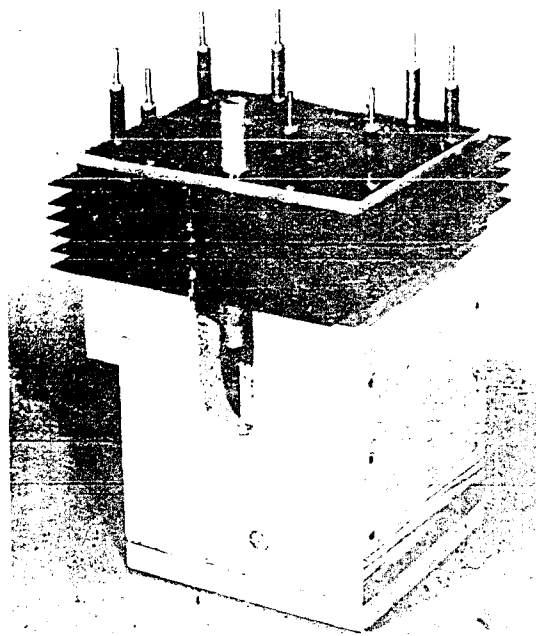Figure 2. Parts of stacked parallel plate cell.

Figure 3. Assembled stacked parallel plate cell.

The top and bottom plates, or end plates, are made of 1/2 x 10 x 12 in. clear plastic; each plate is fitted with a length of plastic pipe to provide an entrance or exit for the solution which passes through the cell. Eight 1/4 in. holes in each end plate, two near each edge, are for passage of the tie rods.

The gaskets are made of 1/4 in. neoprene sheet with outside dimensions 10 x 12 in. and inside dimensions 8 x 10 in. There are eight 1/4 in. holes in each gasket for passage of the tie rods.

The cathode plates are made from 1/64 x 12 x 12 in. titanium sheet; the anodes, from 1/4 x 12-1/2 x 13 in. graphite sheet. A row of 1/4 in. holes near one edge is for passage of solution. Tie rod holes in the cathodes and anodes are either 1/4 in. or 1/2 in. so that when the cell is assembled a 1/4 in. cathode hole is opposite a 1/2 in. anode hole and a 1/2 in. cathode hole is opposite a 1/4 in. anode hole. This hole arrangement prevents shorting of cathode to anode through the tie rods; also, in the assembled cell a 2 x 10 in. strip of the cathode projects beyond the edge of the gasket on one side of the cell and a 2 x 10 in. strip of the anode projects beyond the edge of the gasket on the opposite side. Electrical connections are made at the 1/4 in. hole in the center of these strips near the outside edge. Inside the cell, the solution holes in the anodes and cathodes are on opposite edges (Figure 1); thus, when the cell is in operation, the influent enters through the plastic pipe at the right side of the bottom plastic end plate and flows between the plastic end plate and the first cathode to the left side of the cell. It then rises through the solution holes in the left edge of the first cathode and flows between the first cathode and the first anode to the right of the cell. This flow pattern is repeated until the solution flows between the third cathode and top plastic end plate to the right side of the cell and out of the plastic pipe in the top plate.

The assembled cell is mounted on a wooden stand, the top of which is drilled to receive the tie rods protruding from the bottom plate of the cell; thus, the cell and stand are locked together. Openings are provided in the stand for the entry of the influent pipe.

Electrode Materials

In preliminary tests, stacked parallel plate cells were assembled with three different electrode systems. The first system used Monel anodes and phosphor bronze cathodes. During operation, large amounts

of solid corrosion products were formed in the effluent. The large amounts of solids interfered seriously with the series of analyses necessary to determine available chlorine concentration. The second electrode system, using titanium anodes and mild steel cathodes, was discarded because an impressed voltage of 14 v (volts) was required before a current would flow through the solution. Furthermore, there was considerable corrosion of the mild steel cathodes during non-operating periods. The third electrode system used graphite anodes and titanium cathodes. This system has desirable electrical character-istics and was practically free from corrosion of both the anodes and cathodes during both the operating and non-operating periods.

Auxiliary Equipment

The glass-lined vessels (Figure 4) with capacities of 70 and 55 gallons were used to contain the solutions during multiple pass runs. One served as the influent reservoir and the other as the effluent
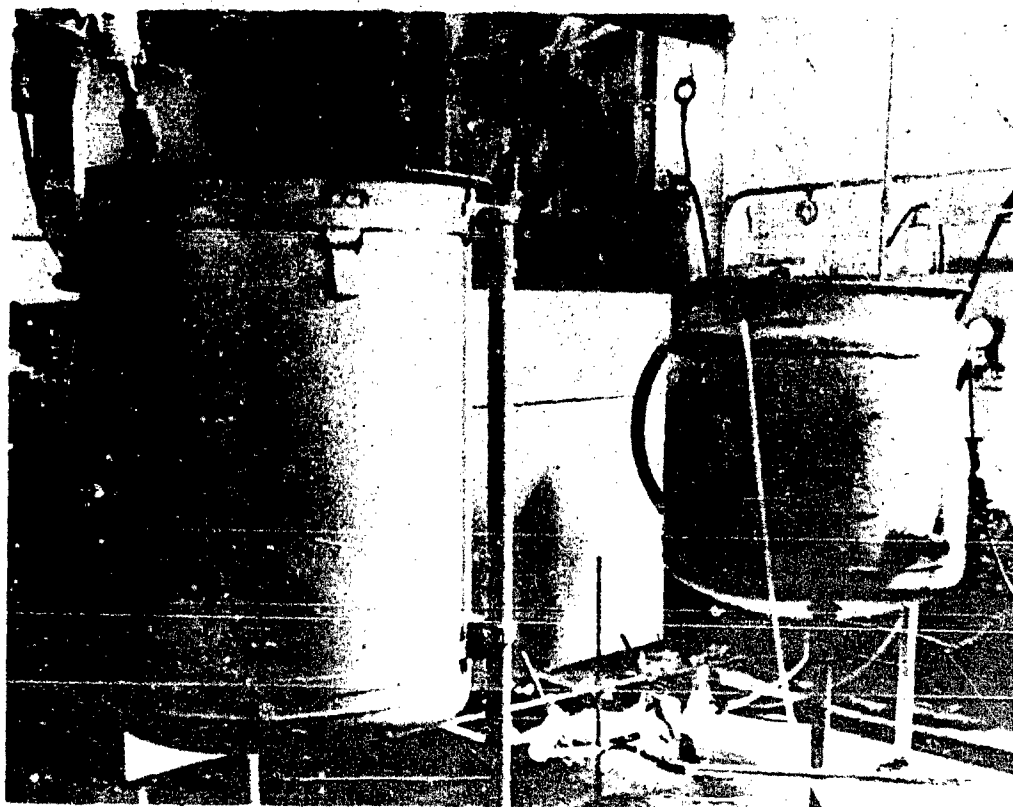
Figure 4. Glass-lined vessels used in multiple pass operation of cells.

receiver. The larger vessel was equipped with a Lightnin model CV4 mixer to aid in dissolving salt when it was added to sea water or fresh (tap) water. Valves necessary for multiple pass operation, a centrifugal pump, an inlet control valve, and a flow meter capable of measuring volumes of from 0.5 to 5.0 gpm (gallons per minute) were installed between the solution container and the first cell. Plastic pipe or tubing was used throughout the system. A heat exchanger was placed between the first and second cells; another between the second cell and the effluent receiver. Four thermometers were located in the system so that the influent and effluent temperatures for each cell could be obtained. Electrical power for the cells was supplied by a Udylite-Mallory Rectoplater with stepwise current control and a maximum capacity of 1440 amps (amperes) at 6 v DC (direct current). A voltmeter and an ammeter were provided for each cell for monitoring of voltage and current during operating runs (Figure 5).
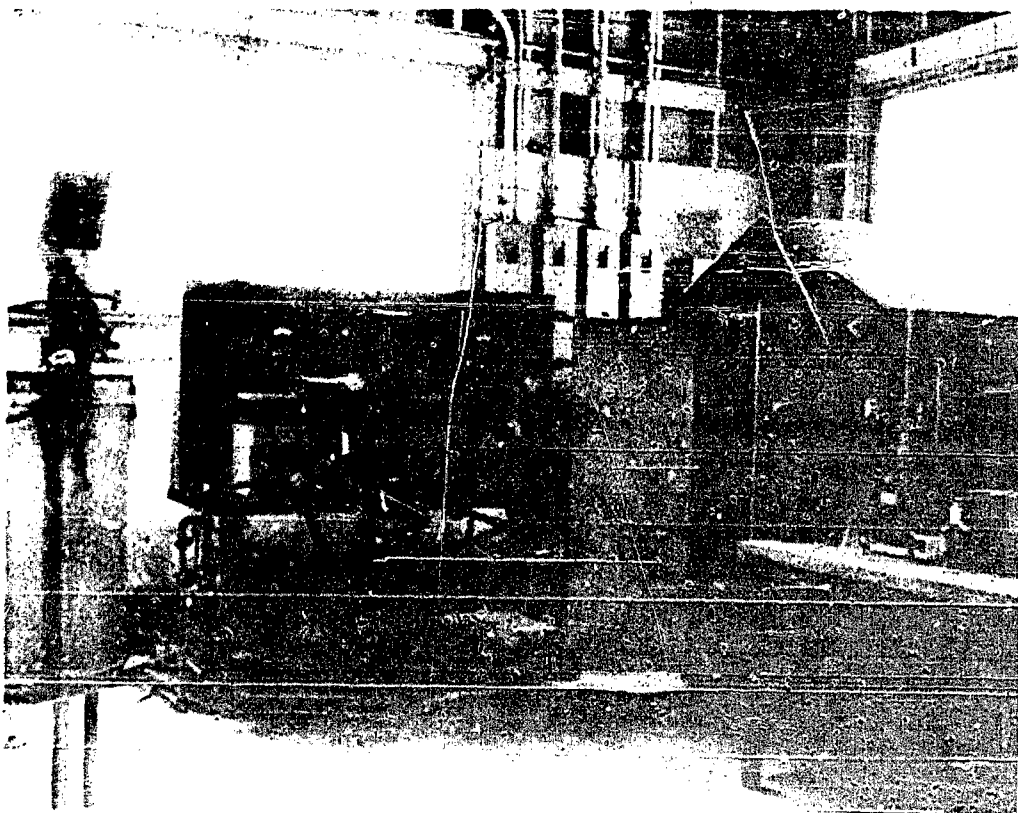
Figure 5. Cells and auxiliary equipment set up for operation.

PROCEDURE

The influent was sea water, sea water containing 2 lb (pounds) per gal (gallon) added salt, sea water saturated with salt, or fresh (tap) water saturated with salt. At the beginning of a run, the centrifugal pump was started and the inlet control valve was adjusted to give the desired flow rate. The power was turned on, and after five minutes the current, voltage, and temperature readings were recorded, and the first sample of the effluent was collected. This sample was titrated by the sodium thiosulfate method to determine the concentration of available chlorine. In multiple pass operation at least two samples were taken during each pass.

When the influent reservoir was nearly empty, the supply valves were adjusted so that the solution in the effluent receiver became the influent for the next pass: the effluent from this pass was collected in the original influent reservoir; thus, the effluent from one pass became the influent for the following pass. This recycling of the solution was continued until a maximum concentration of available chlorine had been obtained and additional runs yielded lower concentrations. An initial run was made with sea water to determine the effect of series operations of cells.

RESULTS

Four different solutions were used at different flow rates. Unless otherwise stated (see Table I) all runs were made through two cells in series.

1. <u>Sea Water</u>. At a flow rate of 1.0 gpm, a single cell produced 0.05 percent (500 ppm)(parts per million) available chlorine in one pass; two cells in series produced 0.09 percent (900 ppm) available chlorine in one pass. No inter-cell cooling was used.

Two runs were made to determine the maximum amount of available chlorine which could be produced from sea water by two cells in series. At 0.5 gpm, 0.82 percent (8200 ppm) was produced in 34 passes with cooling; at 1.0 gpm, 0.75 percent (7500 ppm) was produced in 51 passes with cooling.

Table I. Performance of Two Stacked Parallel Plate Cells

| Influent | Flow Rate (gpm) | Cell 1 | | | | Inter-cell cooling | C | | |
		Voltage (volts)	Current (amp)	Current density (amp/sq. in.)	Power consumption kw		Voltage (volts)	Current (amp)	(an
Sea water	0.5	6.2	88.5	0.276	0.55	Yes	6.2	100.0	
	1.0	8.5	402.0	1.26	3.42	No	*	*	
	1.0	6.8	330.0	1.03	2.24	No	7.2	205.0	
	1.0	5.7	73.0	0.228	0.42	Yes	6.0	74.0	
	1.0	6.1	89.0	0.278	0.54	Yes	6.1	100.0	
Sea water + 2 lb/gal. added salt	0.5	4.9	264.5	0.827	1.30	No	5.7	191.0	
	0.5	4.3	280.5	0.876	1.21	No	5.2	187.0	
	0.5	4.9	147.0	0.460	0.72	Yes	5.8	223.5	
	0.5	5.2	158.5	0.495	0.82	Yes	5.6	225.0	
	1.0	4.6	265.0	0.828	1.22	No	5.6	182.0	
	1.0	4.45	291.0	0.909	1.30	No	5.3	178.5	
	1.0	4.9	275.0	0.859	1.35	Yes	5.85	164.0	
	1.0	5.05	252.5	0.789	1.28	Yes	5.7	172.5	
	1.5	5.0	281.0	0.878	1.41	Yes	6.05	141.0	
	1.5	5.1	285.0	0.890	1.45	Yes	5.9	157.0	
Sea water saturated with salt	0.5	5.3	236.0	0.738	1.25	Yes	6.1	163.0	
	0.5	5.1	250.5	0.782	1.28	Yes	5.9	170.0	
	1.0	4.8	272.5	0.858	1.31	Yes	5.7	166.0	
	1.0	4.75	280.0	0.875	1.33	Yes	5.5	175.0	
	1.5	4.55	278.5	0.860	1.30	Yes	5.6	181.0	
	1.5	4.3	277.0	0.866	1.19	Yes	5.4	180.5	
Tap water saturated with salt	0.5	5.0	250.0	0.781	1.25	Yes	5.6	200.0	
	0.5	4.95	259.5	0.811	1.29	Yes	5.5	184.5	
	1.0	4.9	285.0	0.890	1.40	Yes	6.2	129.0	
	1.0	4.85	286.5	0.895	1.39	Yes	6.0	143.5	

*One cell operated only.

allel Plate Cells Operated in Series.

	Cell II							
ge s)	Current (amp)	Current density (amp/sq. in.)	Power consumption kw	Total Power consumption kw	Number of passes thru cell (s)	Available chlorine (%)	Available chlorine (a/kw hr)	Available chlorine (lb/kw hr)
2	100.0	0.313	0.62	1.17	34	0.82	23	0.05
	*	*	*	3.42	1	0.05	33	0.07
2	205.0	0.640	1.48	3.72	1	0.09	28	0.06
0	74.0	0.231	0.44	0.86	1	0.06	159	0.35
1	100.0	0.313	0.61	1.15	51	0.75	33	0.07
7	191.0	0.598	1.09	2.39	1	0.35	167	0.37
2	187.0	0.584	0.97	2.18	21	1.58	39	0.09
.8	223.5	0.699	1.29	2.01	1	0.37	209	0.46
.6	225.0	0.703	1.26	2.08	22	1.83	45	0.10
.6	182.0	0.569	1.02	2.24	1	0.20	204	0.45
.3	178.5	0.557	0.95	2.25	26	1.36	53	0.12
.85	164.0	0.512	0.96	2.31	1	0.23	226	0.50
.7	172.5	0.539	0.98	2.26	24	1.79	75	0.17
.05	141.0	0.441	0.85	2.26	1	0.13	196	0.43
.9	157.0	0.491	0.92	2.38	25	1.76	101	0.22
.1	163.0	0.510	0.99	2.24	1	0.33	168	0.37
.9	170.0	0.531	1.00	2.28	24	2.03	42	0.09
.7	166.0	0.519	0.95	2.26	1	0.18	181	0.40
.5	175.0	0.547	0.96	2.29	21	1.53	72	0.16
.6	181.0	0.566	1.03	2.33	1	0.13	191	0.44
.4	180.5	0.564	0.98	2.17	25	1.32	83	0.18
.6	200.0	0.625	1.12	2.37	1	0.40	192	0.41
.5	184.5	0.576	1.02	2.31	16	1.55	48	0.11
.2	129.0	0.403	0.80	2.20	1	0.16	165	0.36
.0	143.5	0.448	0.86	2.25	22	1.49	68	0.15

2

2. <u>Sea Water Containing 2 lb per gal Added Salt</u>. At a flow rate of 0.5 gpm, a maximum of 1.58 percent (15,800 ppm) available chlorine was produced in 21 passes without inter-cell cooling; with cooling, a maximum of 1.83 percent (18,300 ppm) available chlorine was produced in 22 passes (Figures 6 and 7). At 1.0 gpm a maximum of 1.36 percent (13,600 ppm) available chlorine was produced in 26 passes without cooling; with cooling a maximum of 1.79 percent (17,900 ppm) was obtained in 24 passes (Figures 6 and 8). At 1.5 gpm a maximum of 1.76 percent (17,600 ppm) was obtained in 25 passes with cooling (Figures 6 and 9).

3. <u>Sea Water Saturated with Salt</u>. Runs were made at three flow rates and inter-cell cooling was used on each run (Figures 7 through 10). At 0.5 gpm, a maximum of 2.03 percent (20,300 ppm) available chlorine was obtained in 24 passes (Figures 7 and 10). At 1.0 gpm, a maximum of 1.53 percent (15,300 ppm) was produced in 21 passes (Figures 8 and 10); at 1.5 gpm, 1.32 percent (13,200 ppm) was produced in 25 passes (Figures 9 and 10).

4. <u>Fresh (Tap) Water Saturated with Salt</u>. Runs were made at two flow rates and inter-cell cooling was used on each run (Figures 7, 8 and 11). At 0.5 gpm, a maximum of 1.55 percent (15,500 ppm) available chlorine was obtained in 16 passes (Figures 7 and 11); at 1.0 gpm, 1.49 percent (14,900 ppm) was obtained after 22 passes (Figures 8 and 11).

5. <u>Effect of Recycling</u>. Recycling the effluent solution through the cells results in a non-linear increase in available chlorine concentration until a maximum is reached; further recycling, even with cooling, causes a decrease in available chlorine concentration.

6. <u>Effect of Cooling</u>. In one typical run, sea water containing 2 lb per gal added salt, the temperature rise, without inter-cell cooling, through two cells in series ranged from 7 - 9°F. The initial influent temperature was 58°F; the influent temperature at the 25th pass was 100°F (Figure 12) and the available chlorine concentration in the effluent was 1.34 percent (Figure 13). In the experimental setup used, cooling of the solution did occur during its storage in the effluent reservoir. There the solution temperature decrease ranged from 3°F between the first and second pass to 7°F between the twenty-fourth and twenty-fifth pass.
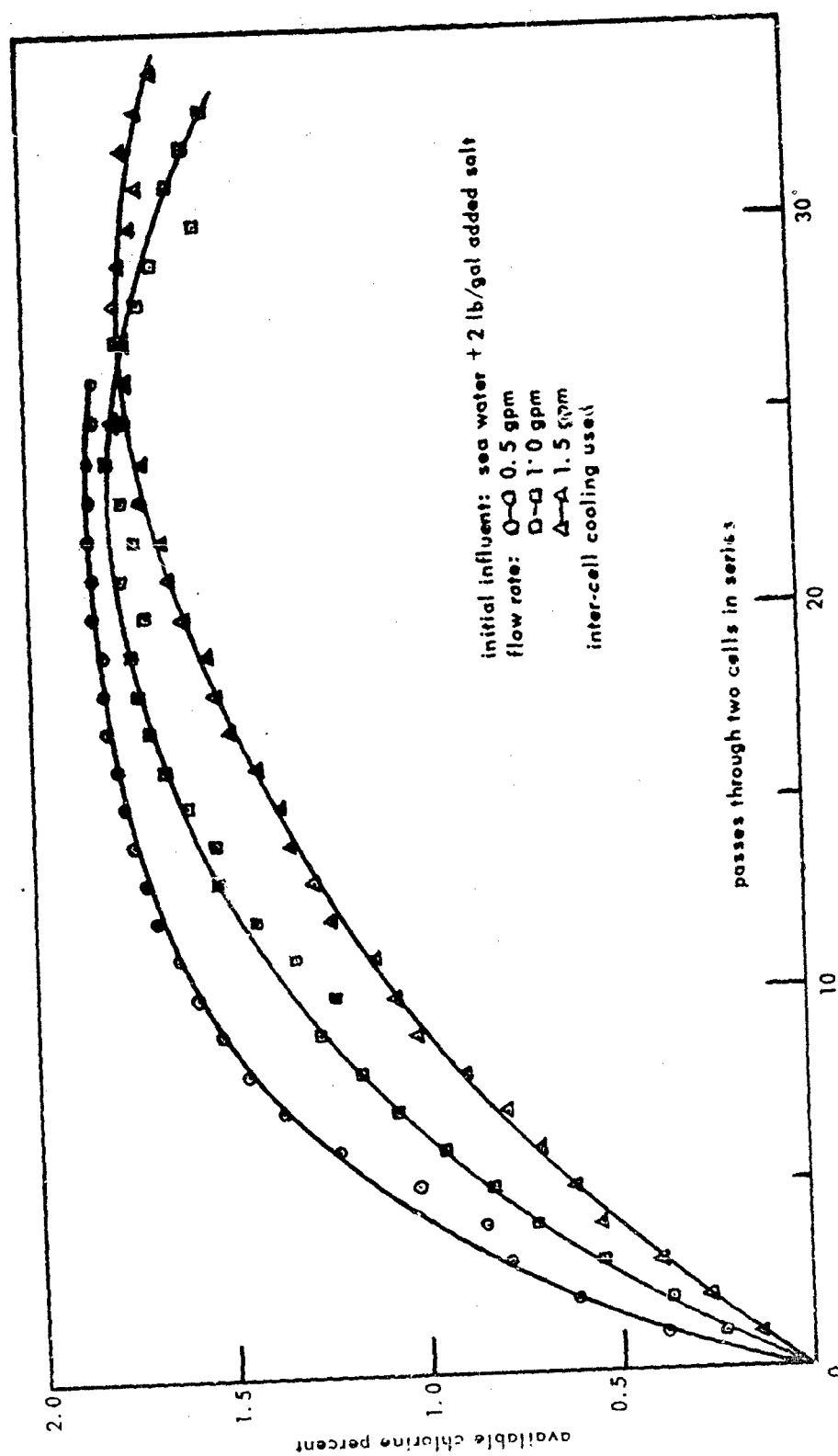
14

Figure 6. Effect of flow rate on the production of available chlorine from sea water plus 2 lb/gal added salt.
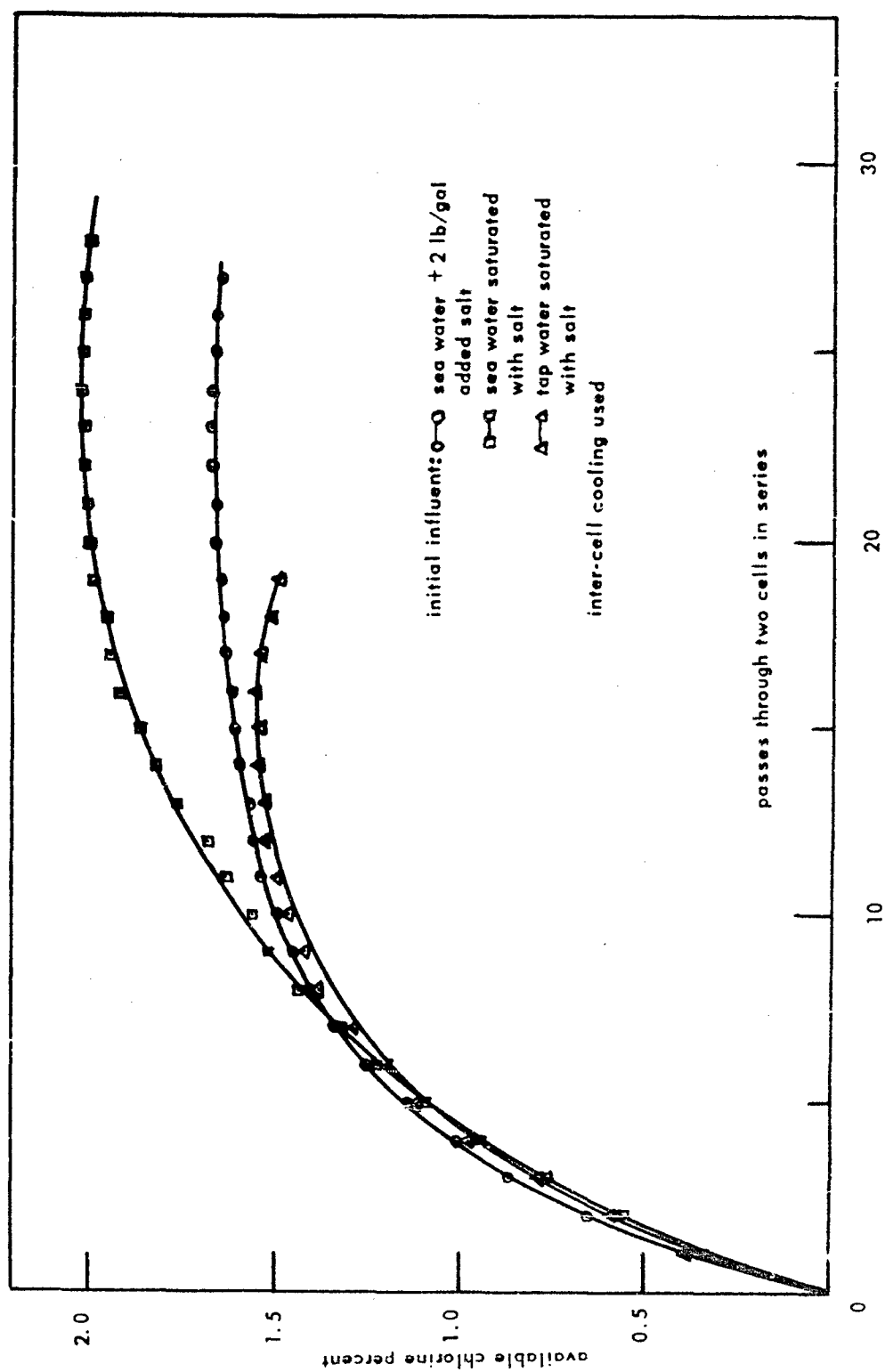
Figure 7. Effect of addition of salt to sea water and fresh (tap) water on production of available chlorine at 0.5 gpm.
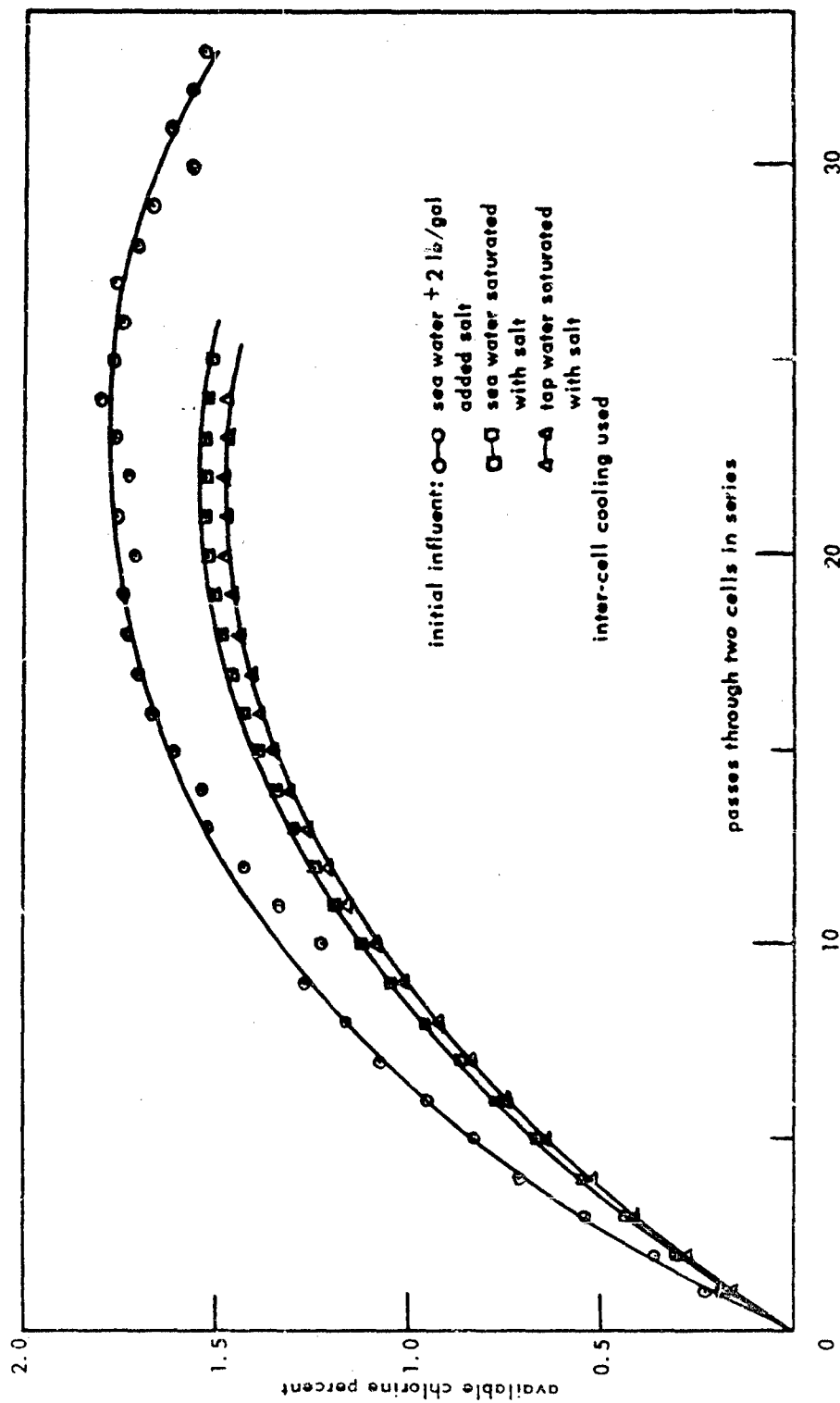
Figure 8. Effect of addition of salt to sea water and fresh (tap) water on production of available chlorine at 1.0 gpm.
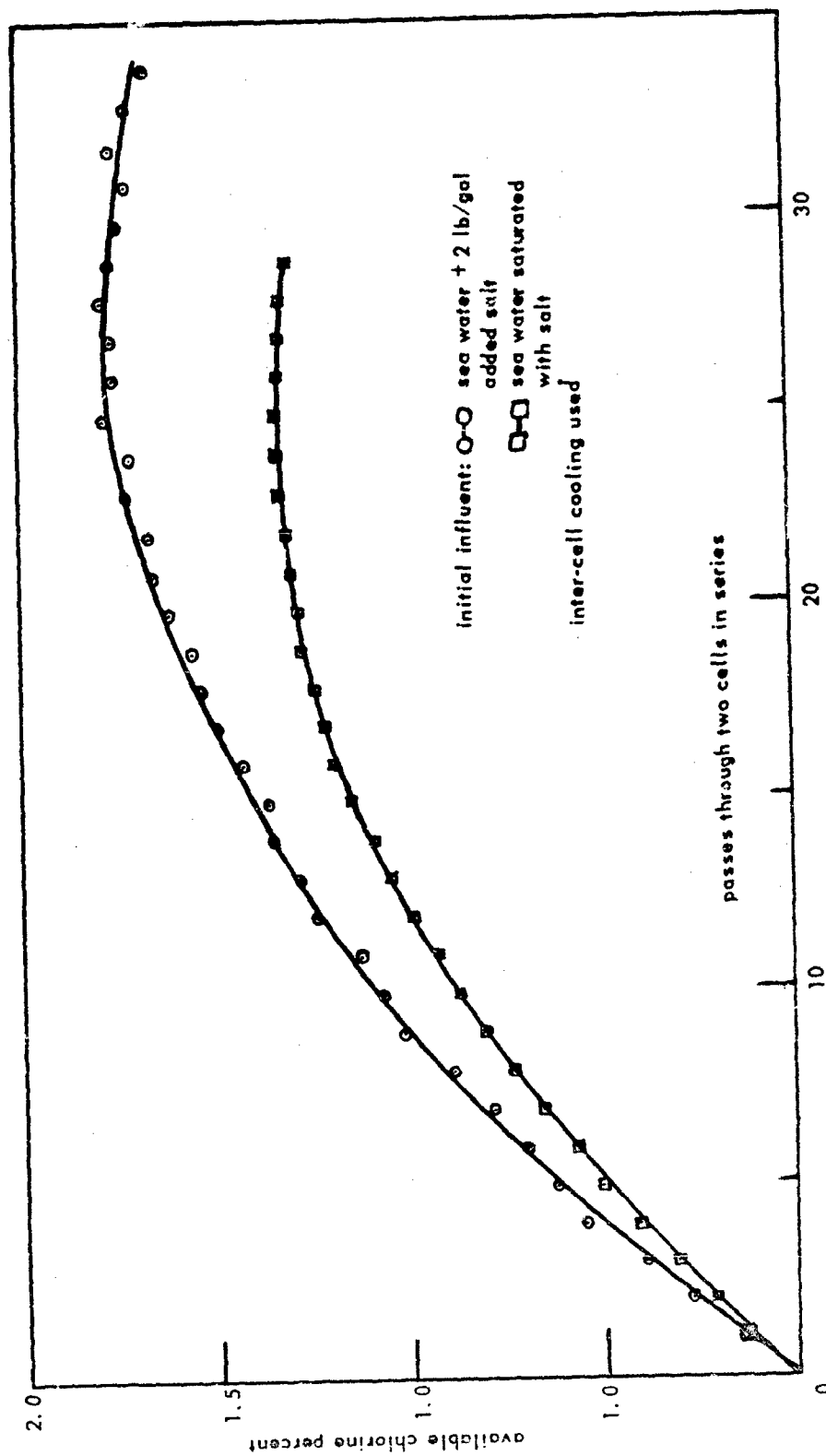
Figure 9. Effect of addition of salt to sea water on the production of available chlorine at 1.5 gpm.

Figure 10.   Effect of flow rate on the production of available chlorine from sea water saturated with salt.
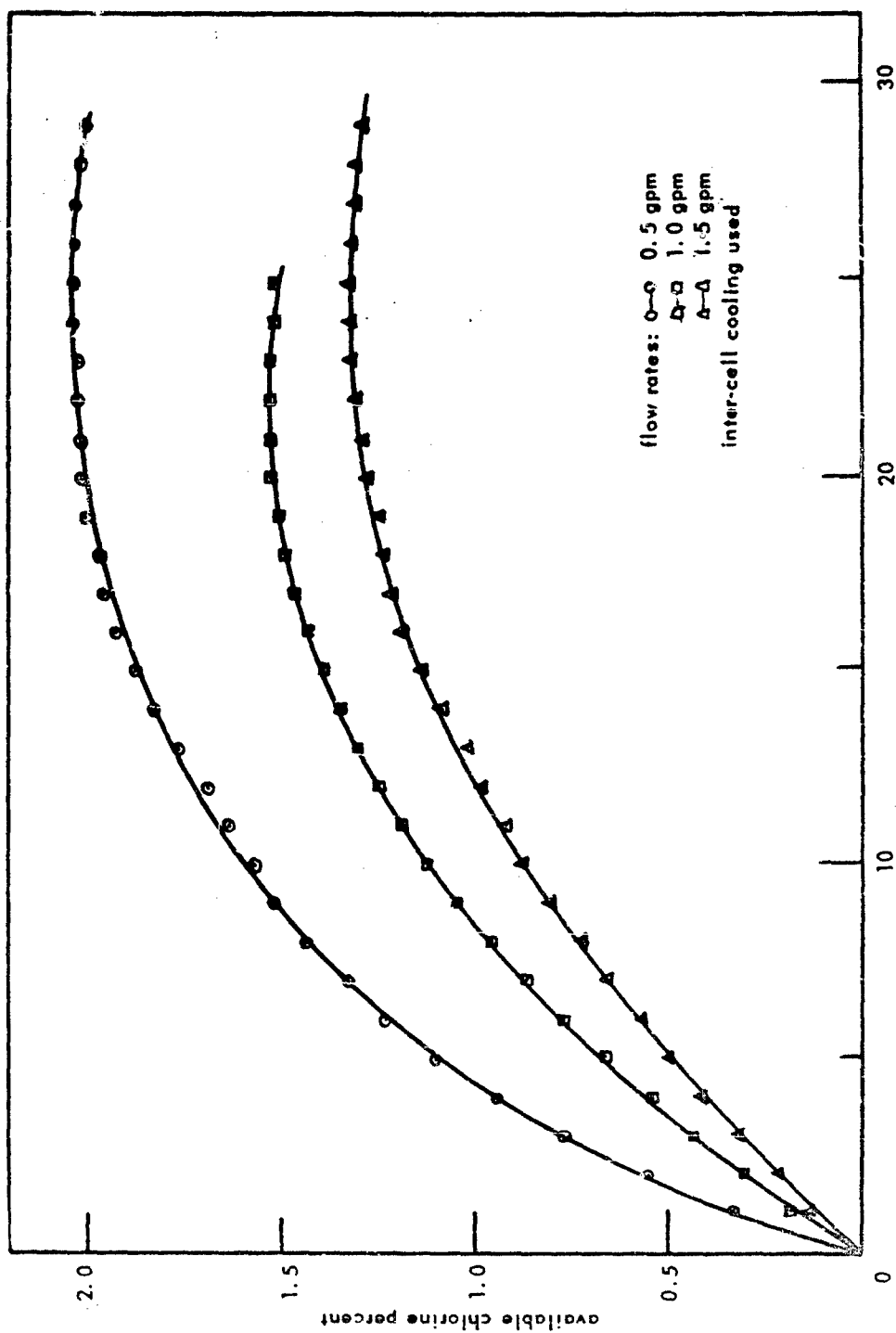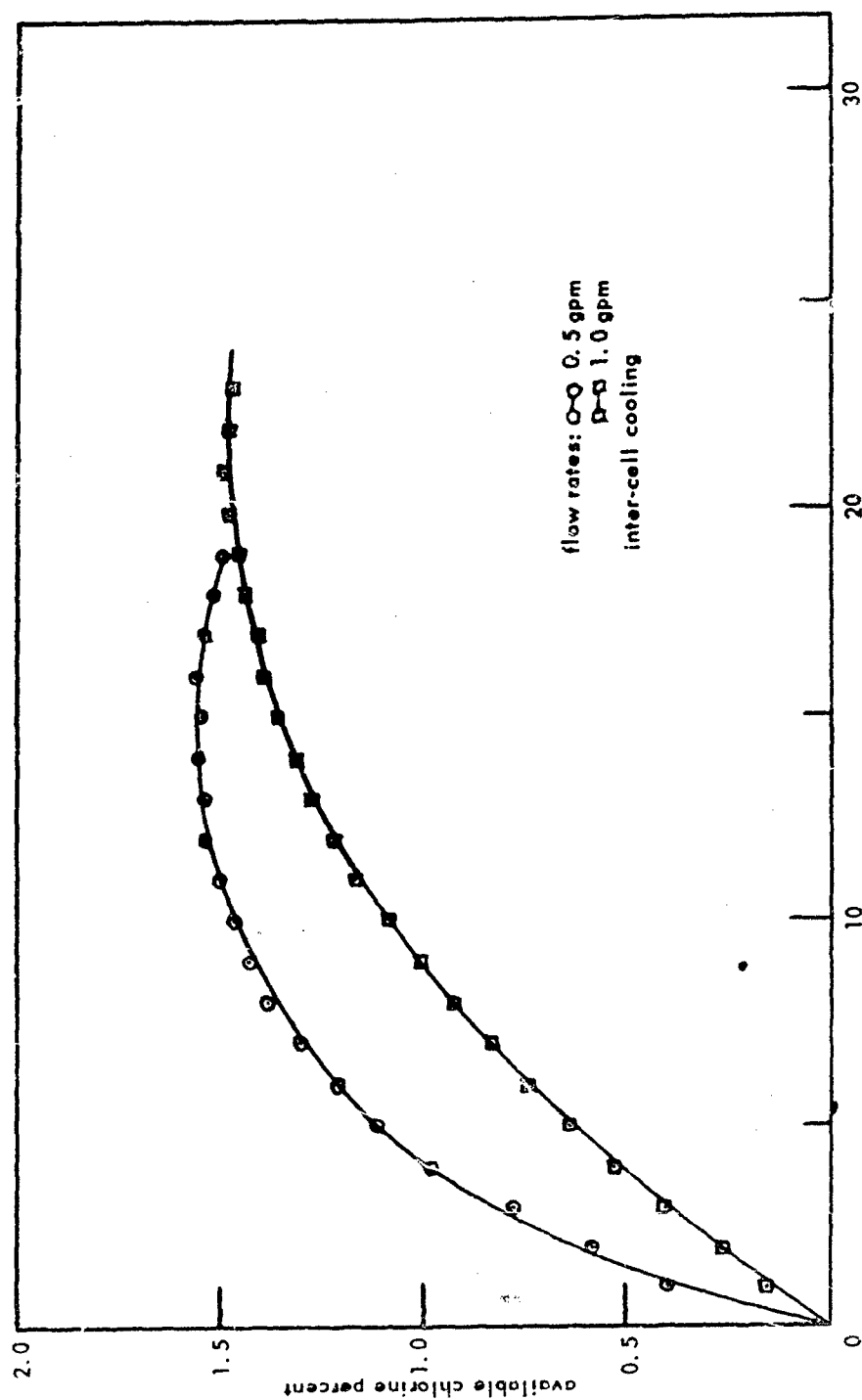
Figure 11. Effect of flow rate on the production of available chlorine from fresh (tap) water saturated with salt.
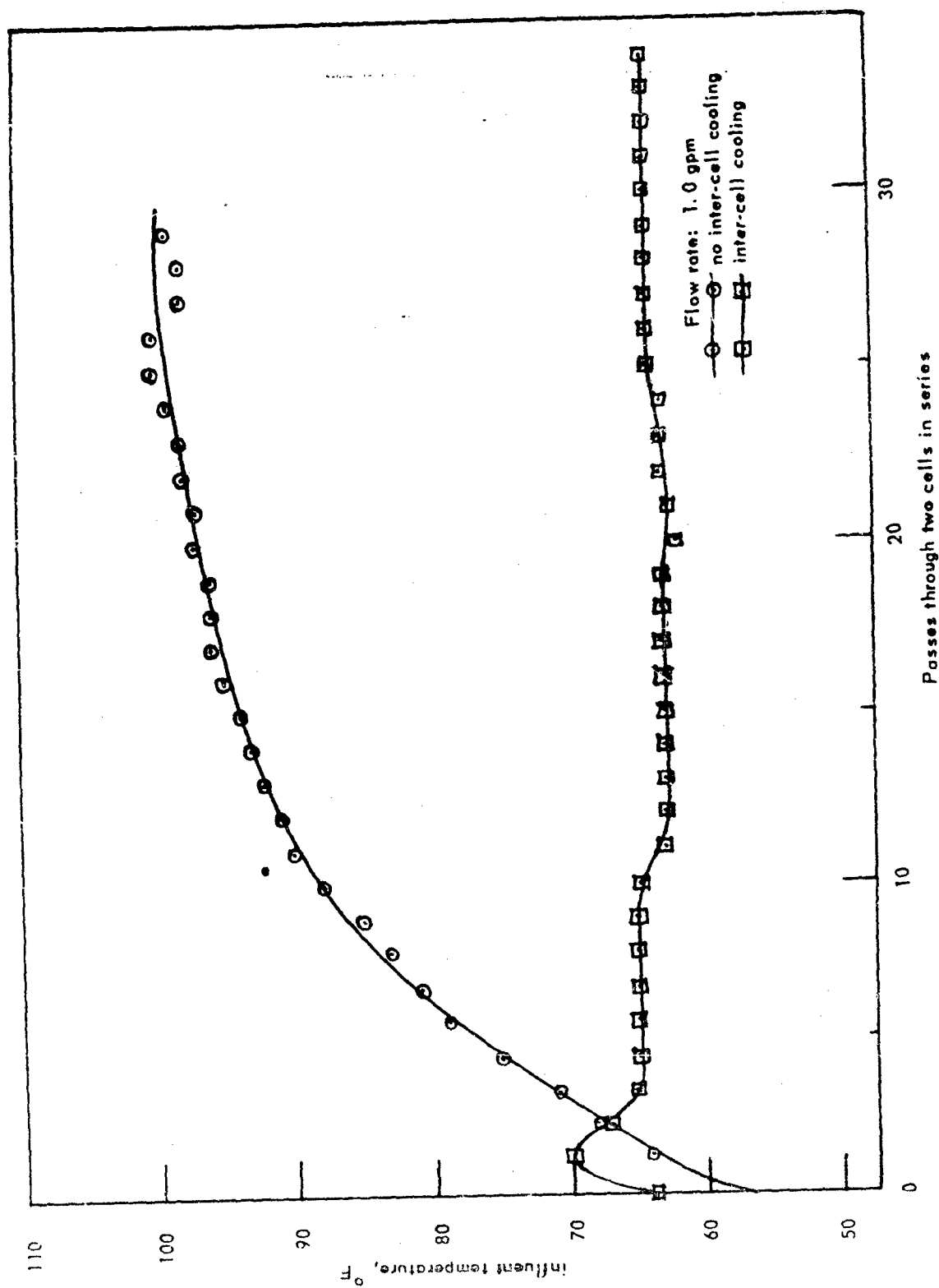
Figure 12. Effect of inter-cell cooling on the temperature rise of a solution of *sea* water plus 2 lb/gal added salt.
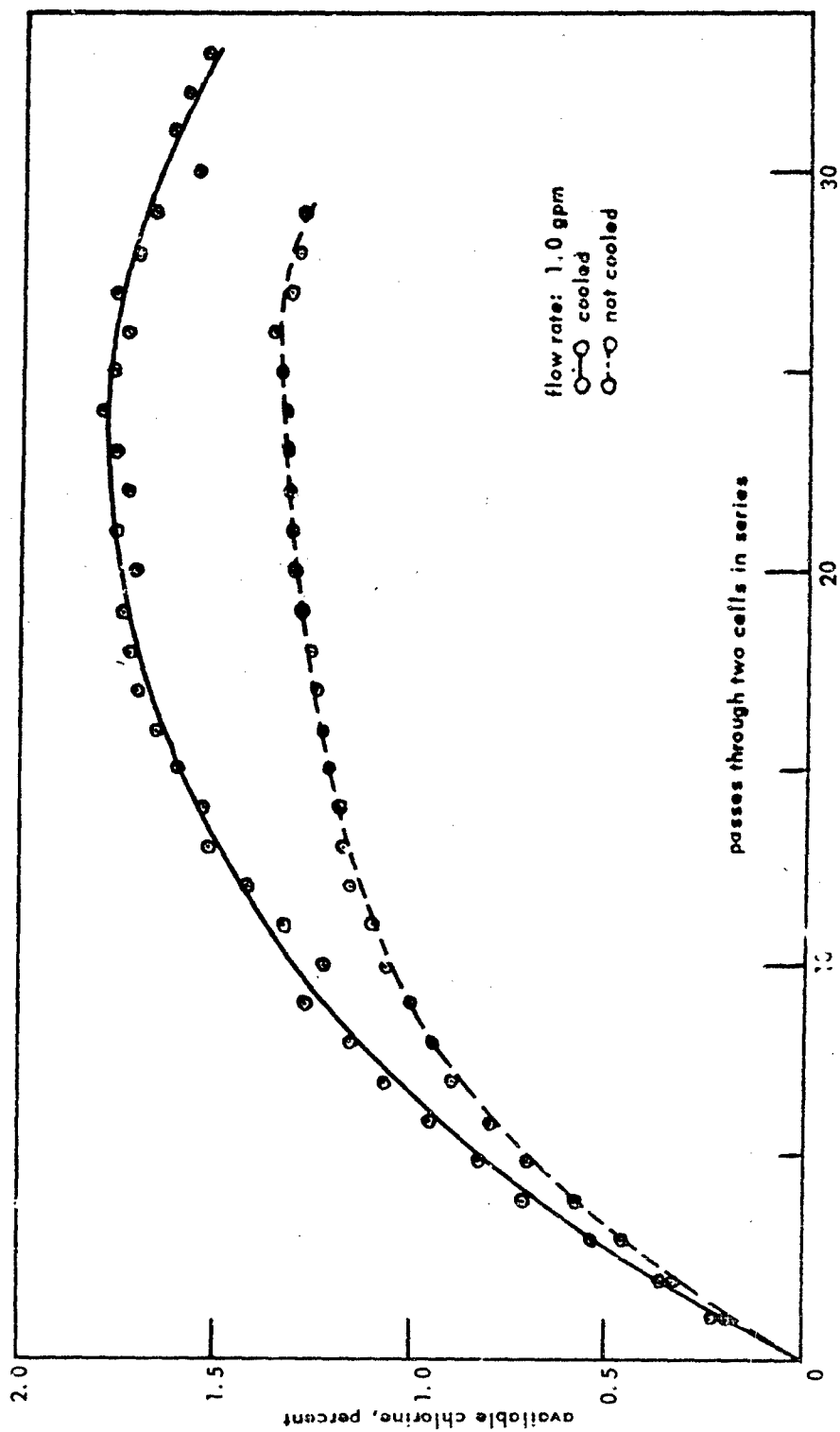
Figure 13. Effect of inter-cell cooling on production of available chlorine from sea water plus 2 lb/gal added salt.

In another run, with inter-cell cooling, the temperature rise through two cells in series ranged from 8 - 10°F. The initial influent temperature was 64°F and the influent temperature at the beginning of the twenty-fifth pass was still 64°F (Figure 12); and, the available chlorine concentration in the effluent was 1.76 percent (Figure 13). Thus, the amount of cooling supplied by heat exchangers in addition to that which occurred in the effluent reservoir was sufficient to maintain the initial influent temperature.

DISCUSSION

The stacked parallel plate cell can be quickly assembled from simple component parts: its design allows for maximum flexibility in the choice of the number of plates, thickness of the plate materials, and spacing between the plates. The efficiency of the cells could be increased by varying the number of plates and the spacing between the plates until optimum cell performance is achieved. The maximum size of the cell would be determined by the largest sized graphite plates which are available and by the temperature increase of the solution on passage through the cell.

Because of this heating effect, which is caused by the resistance of the solution to the flow of current between the anodes and cathodes, the cell with maximum efficiency should have a small number of plates. But a cell with only a few plates will yield small amounts of available chlorine per pass even when operating at high efficiency. Recycling of the solution through the cell will increase the available chlorine concentration, but during this operation the solution is not available for decontamination use; thus, to achieve a high output of available chlorine together with high electrical efficiency and instant availability of the solution for use, passage of the solution through a series of cells would be preferred to an equal number of passes through a single cell. For example, one pass through two cells in series will yield the same quantities of available chlorine as two passes through a single cell; thus, one pass through 20 cells in series should yield the same quantity of available chlorine as that produced by 20 passes through a single cell. Cooling of the solution between the cells reduces the decomposition of the sodium hypochlorite formed in the electrolysis and thus, gives a higher maximum concentration of available chlorine.

For a more efficient operation, a series-parallel flow arrangement could be used. Table II and Figure 14, for example, show that five passes at 0.5 gpm through two cells in series (or one pass through ten cells in series) yielded 1.10 percent available chlorine from 11.10 kw (kilowatts) of power. They also show that 20 passes at 0.5 gpm through

Table II. Typical Run: Sea Water Saturated with Salt Flowing at 0.5 gpm through Two Stacked Parallel Plate Cells in Series.

| No. of passes thru two cells in series	Power consumption per pass kw	Total Power consumption kw	Available chlorine		
			%	gm/kw hr	lb/kw hr
1	2.24	2.24	0.33	168	0.37
2	2.19	4.43	0.55	141	0.31
3	2.26	6.69	0.76	129	0.28
4	2.21	8.90	0.95	121	0.27
5	2.20	11.10	1.10	112	0.25
6	2.19	13.29	1.23	105	0.23
7	2.18	15.47	1.32	97	0.21
8	2.26	17.73	1.44	92	0.20
9	2.21	19.94	1.52	88	0.19
10	2.16	22.10	1.56	80	0.18
11	2.19	24.29	1.63	76	0.17
12	2.17	26.46	1.69	73	0.16
13	2.28	28.74	1.76	70	0.15
14	2.29	31.03	1.82	67	0.15
15	2.24	33.27	1.87	64	0.14
16	2.25	35.52	1.93	62	0.14
17	2.26	37.78	1.95	59	0.13
18	2.29	40.07	1.96	56	0.12
19	2.27	42.34	2.00	54	0.12
20	2.25	44.59	2.01	51	0.11
21	2.28	46.87	2.01	49	0.11
22	2.22	49.09	2.02	47	0.10
23	2.26	51.35	2.02	45	0.10
24	2.28	53.63	2.03	43	0.09
25	2.26	55.89	2.02	41	0.09
26	2.25	58.14	2.02	40	0.09
27	2.28	60.42	2.02	38	0.08
28	2.27	62.69	2.01	36	0.08
29	2.29	64.98	2.00	35	0.08
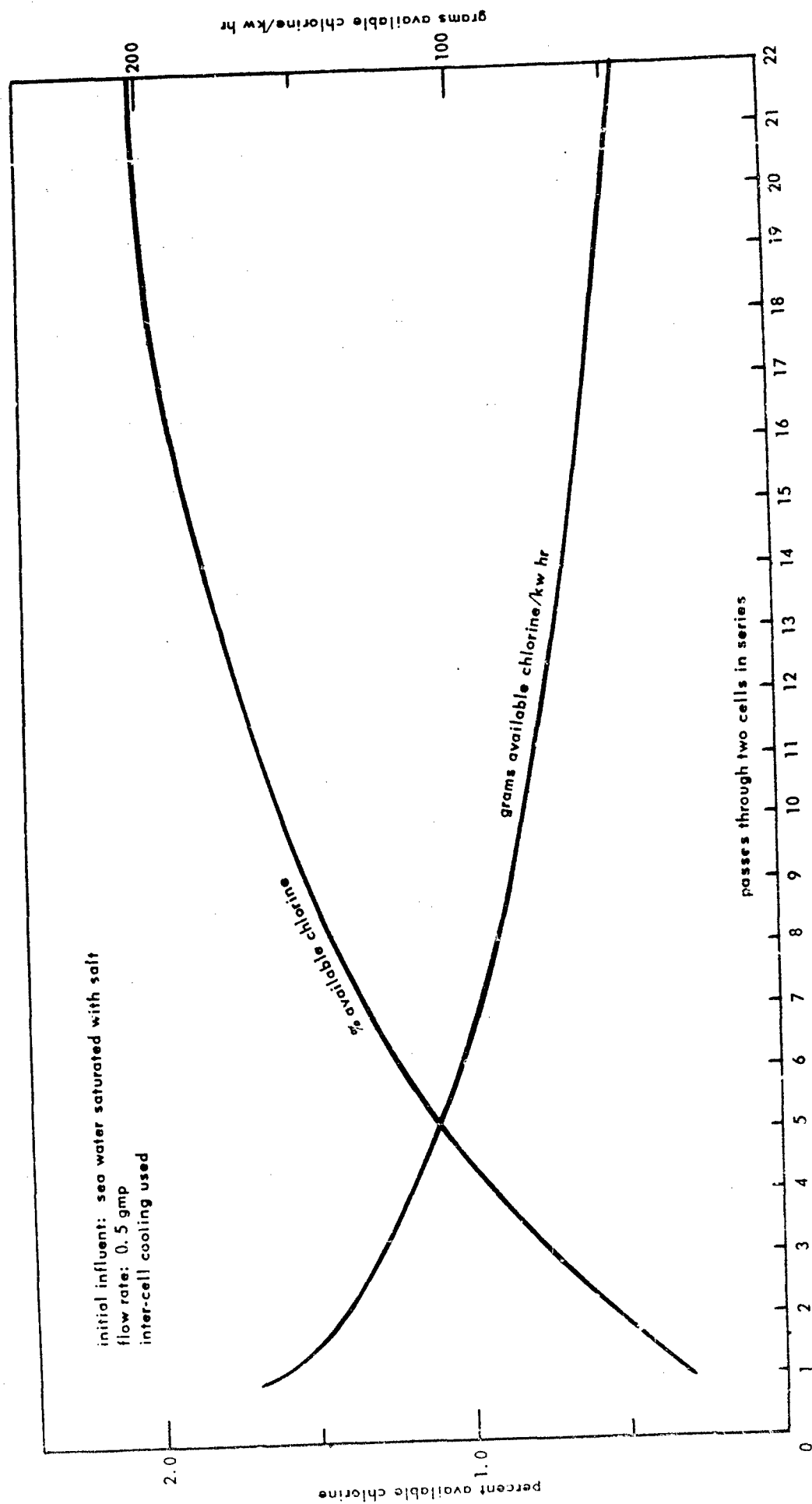
Figure 14. Available chlorine production versus power efficiency in multiple pass operation of two cells in series.

24

two cells in series (or one pass through 40 cells in series) yielded 2.01 percent available chlorine from 44.59 kw of power. This is equal to 1.0 gpm of a one percent available chlorine solution from 44.59 kw of power. If, however, the 40 cells were arranged in four banks of 10 cells in series, each bank of 10 cells would produce 1.10 percent available chlorine at 0.5 gpm, or a total of 1.10 percent available chlorine at 2.0 gpm, and the power required would be 44.40 kw; thus, for the same amount of power, 40 cells in four banks of 10 each would produce twice the quantity of available chlorine as 40 cells in series.

Electrolytic production of sodium hypochlorite decontaminating solution from fortified sea water costs less than the use of prepared hypochlorites for this purpose. For example, the cells used in this phase of the project yielded a maximum of 0.50 lb of chlorine per kilowatt hour; thus, the production of a solution containing one percent available chlorine at a flow rate of 50 gpm would require 500 kw hr of energy (see Table III).

Table III. Power Required to Produce Various Quantities of Available Chlorine at Different Flow Rates.

Flow rate (gpm)	Available chlorine (%)	Available chlorine lb/hr	Power required kw*
10	1	50	100
10	2	100	200
20	1	100	200
20	2	200	400
50	1	250	500
50	2	500	1000

*Based on production of 0.50 lb chlorine per kw hr.

The cost of operation of two 300 kw diesel driven generator sets is approximately $2.50 per hour; if 2 lb of salt are added per gallon of sea water, this would cost $60.00 per hour; thus, the total cost (less labor) for the production of 50 gpm of a one percent available chlorine solution for one hour would be $62.50. Assuming that operation for 7 days would be required, the operating cost for this period would be $10,500 and 1,008,000 lb of salt would be required. The maximum available chlorine concentration which can be produced is two percent. The cost of an equal volume of solution of the same concentration for the same length of time from STB containing 30 percent available chlorine (cost: $0.13 per lb) plus anti set would be about $109.00. Operation for 24 hr per day for seven days by this method would cost $18,300 and would require 133,000 lb of STB and 665 lb of anti set.

In cost of equipment, however, the electrolytic system is much higher; two AC (alternating current) generators would cost $105,000 and the rectifying equipment $72,000. To eliminate the need for expensive rectifying equipment, two 300 kw DC generators would have to be used; these would cost about $100,000. Add to this the large number of cells plus the necessary cooling equipment, valves, pumps, and piping, and the initial cost would probably be $250,000. In comparison, the chemical method requires only an M3A2 decontaminating truck, (cost $9300), which is equipped with a 400-gal tank and is capable of pumping 20 gpm of solution; in addition, this method will produce up to 12 percent available chlorine while the electrolytic system will only produce up to 2 percent.

CONCLUSIONS

Based on the experimental findings, the conclusions are as follows:

1. Operation of two stacked parallel plate electrolytic cells in series produces as much sodium hypochlorite as two passes through a single cell.

2. At comparable current densities, addition of 2 lb of salt per gallon of sea water yields more than twice the quantity of available chlorine as that which can be produced from sea water.

3. The highest efficiency in producing available chlorine occurs in the first pass, and then decreases as the available chlorine concentration increases.

4. Cooling of the effluent between cells gives higher yields of available chlorine than can be obtained without cooling.

5. The cells can produce up to 2.03 percent (20,300 ppm) of available chlorine at 0.5 gpm; this is equivalent to 0.02 percent (200 ppm) at a flow rate of 50 gallons per minute.

6. Use of a series-parallel flow system in operation of the cells gives higher available chlorine concentrations per unit of power than straight series flow operation.

7. The electrolytic production of large volumes of sodium hypochlorite solution can be used for concentrations containing up to 0.2 percent (2000 ppm) available chlorine; however, power requirements are high and extensive auxiliary equipment is needed.

RECOMMENDATIONS

1. Electrolytic production of sodium hypochlorite should be used only when available chlorine concentrations of less than 0.2 percent are desired, and when standard chemical methods are not available.

2. Electrolytic cells should be stacked parallel plate type.

3. Graphite anodes and titanium cathodes should be used in the cells.

4. Cells should be operated in a series-parallel flow pattern; the effluent should be cooled between cells.

DISTRIBUTION LIST

No. of
Copies

10	Chief of Civil Engineers
408	Standard Distribution List
20	Supplemental Distribution List

UNCLASSIFIED

AD 201641

Armed Services Technical Information Agency

ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA

FOR

MICRO-CARD

CONTROL ONLY

1 OF 1